sity can be achieved. Moreover, any negative effects of laser machining are mitigated, due to lower pulse energy, suitable wavelength, and shorter pulse duration. At the same time, relatively high material removal rates can be achieved,

[0079] With continuing reference to FIG. **14**, the laser beam delivery system **256**, coupled to the laser source **252**, transmits one or more beams **258** on a surface **260** of a sample **262**. (The sample is illustrated in simple block form, but could be in the shape of a turbine blade, as described previously). In some embodiments, the laser beam delivery system **256** employs a mirror-lens-machining head based beam delivery. In other embodiments, a fiber-machining head based beam delivery may be employed. In some cases, the laser beam delivery system may employ an optical galvanometer scanner based beam delivery.

[0080] A motion system **262** is further coupled to the laser beam delivery system **256**, to synchronize the relative location between laser beam firing and the sample **262**. A monitoring subsystem **264** detects the location of the laser path, and the progress of the laser machining. In a typical embodiment, the monitoring subsystem **264** also collects the laser operation-information, and communicates back and forth with a control subsystem or a processor **266**. The subsystem/processor can automatically stop the laser machining, and direct movement to a next machining location, when desired. In a typical system design, the control subsystem **264** is in communication with the laser source **252**, the laser beam delivery system **256**, the monitoring subsystem **266**, and the motion system **262**. Other relevant details regarding this type of system are provided in patent application Ser. No. 12/435,547. As in the case of the water jet system and the EDM apparatus, a laser-based system as described herein can be employed to precisely form the passage hole and exit geometry required for this invention.

[0081] Several additional variations and considerations should be noted. The processes described herein can be used to form an entire passage hole, i.e., including the preferred chevron outlet. However, they can also be used to form only the chevron outlet, e.g., as an extension of a passage hole (inlet bore) thas has previously been formed within a substrate.

[0082] Moreover, a combination of the techniques described previously can be used to form the passage holes, or portions thereof. For example, the main portion of the passage hole, i.e., the inlet bore, could be formed by a laser drilling technique, and then the desired chevron outlet could be formed by an EDM or water jet technique. Other variations may also be possible. Several examples of combining different hole-forming techniques are provided in U.S. Pat. No. 4,808,785 (Vertz et al; incorporated herein by reference), although that teaching is not related to the particular chevron outlets required for the present invention.

EXAMPLE

[0083] The examples presented below are intended to be merely illustrative, and should not be construed to be any sort of limitation on the scope of the claimed invention.

[0084] Modeling studies were carried out on film cooling effectiveness, as a function of the (X/Ms) value, for a number of different, modeled shapes. (The non-dimensional distance "X/Ms" is the ratio of the axial distance "x" along the cooled surface, starting at the film hole exit, to the product of M*s, where "M" is the blowing ratio, and "s" is the equivalent two-dimensional slot height representing the same flow area as the film hole bore cross-section). In one instance, a standard diffuser-type passage hole was evaluated, i.e., a passage hole with no chevron characteristics at the hole exit, instead terminating in a standard, trapezoidal shape. Chevron-shaped holes which generally conform to the chevron geometry specified in U.S. Pat. No. 7,328,580 (Lee et al, discussed previously) were also evaluated, along with a chevron-based geometry formed by the multi-plunge technique described herein. The studies showed that the all of the chevron-shaped holes, including those formed by the multiplunge technique, exhibited a desirable level of cooling effectiveness.

[0085] Various embodiments of this invention have been described in rather full detail. However, it should be understood that such detail need not be strictly adhered to, and that various changes and modifications may suggest themselves to one skilled in the art, all falling within the scope of the invention as defined by the appended claims.

What is claimed:

1) An article in the form of a substrate, comprising:
a) an inner surface , including an inlet;
b) an outer surface spaced from said inner surface; and
c) at least one row or other pattern of passage holes, wherein each passage hole includes an inlet bore extending through the substrate from the inlet at the inner surface to a passage hole-exit proximate to the outer surface, with the inlet bore terminating in a chevron outlet adjacent the hole-exit, said chevron outlet comprising a pair of wing troughs having a common surface region between them;
wherein the common surface region comprises a valley which is adjacent the hole-exit; and a plateau adjacent the valley.

2) The article of claim **1**, wherein:
each passage hole is inclined between the inner and the outer surface;
the wing troughs diverge longitudinally between the passage hole and the outer surface, and laterally along the common surface region; and
the shape and size of the plateau and its surrounding common surface region maximizes diffusion of cooling air channeled through the passage holes from the inner surface to the outer surface, with minimal flow separation of the cooling air from the outer surface.

3) The article of claim **2**, wherein the inlet bore terminates below the outer surface; and the troughs decrease in depth along the common surface region in a direction away from the inner surface, to blend with the outer surface.

4) The article of claim **1**, wherein each wing trough has a total length-dimension extending from the hole exit to a terminus farthest from the hole exit; and substantially all of the plateau extends above the common surface region defined by a portion of the total-length which is greater than about 40% of the distance from the outlet to the terminus.

5) The article of claim **1**, wherein the plateau is generally in the shape of a triangle or a trapezoid.

6) The article of claim **1**, wherein the plateau is generally in the shape of a triangle; and a vertex of the triangle-shaped plateau lies generally in a mid-point area between the two troughs, and above a portion of the common surface region, said vertex generally pointing toward the hole exit.

7) The article of claim **1**, wherein the height of the plateau has a dimension which is about 2% to about 20% of the length-dimension extending from the passage hole-exit to a terminus farthest away from the hole-exit.